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Polymerized Membranes, a Review

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Abstract

Membranes are of great technological and biological as well as theoretical interest. Two main classes of membranes can be distinguished: Fluid membranes and polymerized, tethered membranes. Here, we review progress in the theoretical understanding of polymerized membranes, i.e. membranes with a fixed internal connectivity. We start by collecting basic physical properties, clarifying the role of bending rigidity and disorder, theoretically and experimentally as well as numerically. We then give a thorough introduction into the theory of self-avoiding membranes, or more generally non-local field theories with δ-like interactions. Based on a proof of perturbative renormalizability for non-local field-theories, renormalization group calculations can be performed up to 2-loop order, which in 3 dimensions predict a crumpled phase with fractal dimension of about 2.4; this phase is however seemingly unstable towards the inclusion of bending rigidity. The tricritical behavior of membranes is discussed and shown to be quite different from that of polymers. Dynamical properties are studied in the same frame-work. Exact scaling relations, suggested but not demonstrated long time ago by De Gennes for polymers, are established. Along the same lines, disorder can be included leading to interesting applications. We also construct a generalization of the $O(N)$-model, which in the limit $N \to 0$ reduces to self-avoiding membranes in analogy with the $O(N)$-model, which in the limit $N \to 0$ reduces to self-avoiding polymers. Since perturbation theory is at the basis of the above approach, one has to ensure that the perturbation expansion is not divergent or at least Borel-summable. Using a suitable reformulation of the problem, we obtain the instanton governing the large-order behavior. This suggest that the perturbation expansion is indeed Borel-summable and the presented approach meaningful. Some technical details are relegated to the appendices. A final collection of various topics may also serve as exercises.

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